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Abstract: **BACKGROUND:** To report the authors' experience with recurrent aneurysms after primarily completely clipped cerebral aneurysms and discuss mechanisms of recurrence and recommended management. **METHODS:** Data were available for 1016 consecutive patients who underwent clipping of ruptured and unruptured aneurysms in a 15-year period from 1993-2007. **RESULTS:** Nine patients were treated for recurrent aneurysms after successful complete clipping of the initial aneurysms; six patients had initial surgery before 1992, and three patients underwent surgery during the study period. Mean elapsed time between the first clipping and the recurrence of aneurysm was $13.3 \text{ years} \pm 7.8$. Repeat craniotomy was performed in seven patients, and six patients underwent reclipping of aneurysms with or without removal of the old clips. One patient was treated by construction of an extracranial-intracranial (EC-IC) bypass plus coating of the aneurysm. Endovascular occlusion of the parent artery was performed in one patient. One patient died without any intervention. Recurrent aneurysms could be classified into three types according to the relationship of the new aneurysm neck to the old clip. **CONCLUSIONS:** The incidence of recurrent aneurysms after complete clipping was approximately 0.02% per year; aneurysms recurred after 13.3 years on average with 25 years the longest duration from initial clipping to recurrence. Classification of recurrent aneurysms into three types might be helpful in selecting appropriate surgical management.

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Recurrent intracranial aneurysms after successful neck clipping

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Abstract

Background: We report our experience on recurrent aneurysms after primarily completely clipped cerebral aneurysms. Mechanism of recurrence and its recommendable management are discussed. Methods: The database consisted of 1016 consecutive patients who underwent clipping of ruptured and unruptured aneurysms in an 15 years period from 1993 through 2007. Results: Out of these patients, 9 patients were found to be treated for recurrent aneurysms after successful complete clippings of initial aneurysms : 6 patients initial surgery before 1992, while 3 patients during the period. Mean elapsed time between their first clipping and the recurrence of aneurysm was 13.3 ± 7.8 years. Recraniotomy was performed in 7 patients, in which 6 patients underwent reclipping of the aneurysms with or without removal of the old clips. One patient was treated by construction of extracranial-intracranial EC-IC bypass plus coating of the aneurysm. Endovascular occlusion of the parent artery was performed in one patient and the rest one patient expired without any. Recurrent aneurysms could be classified into 3 types according to the relation of their new aneurysm neck to the old clip. Conclusion: Recurrent aneurysms after complete clipping occurred around 0.02 %/year and took place after a period of 25 years at longest and 13.3 years on the average. Classification of recurrent aneurysms into three types might serve to select their appropriate surgical management.

Key words: recurrent aneurysm, microsurgical clipping, subarachnoid hemorrhage

1. Introduction

Recurrent aneurysms after their initial clipping have been an important issue in the management aneurysm surgery and often discussed, since McKissock reported a case of middle cerebral artery MCA aneurysm on the left side fatally bled into the temporal lobe. She had been operated upon 11 years before but on the right side, in which the aneurysm neck of the right MCA was occluded with 2 tantalum clips followed by excision of the sac but a recurrent multilobular unruptured aneurysm was noticed at the site of the clips on the autopsy [1]. The patient having clipped aneurysm might have thus, like in this case, following risks concerning new aneurysm formation on the long term follow-up: recurrent aneurysm at completely clipped and/or incompletely clipped aneurysm, and de novo aneurysm. Although the frequency of aneurysm recurrence after complete clipping is difficult to determine, their incidence have been reported to be around 0.26-0.53 % annually [2,3,4]. Surgical treatment for regrowth of a previously clipped aneurysm is regarded to be one of the most difficult procedures in aneurysm surgery. A recent analysis based on technical difficulty in reoperations for aneurysms considered that late reoperation is more challenging than early reoperation because of the attendant scar formation where a large portion of the sac need to be dissected to ensure complete reclipping, thereby requiring advanced technical expertise [5,9,17]. The purpose of this paper is to describe our experience on recurrent aneurysms after complete neck clipping and their management.

2. Methods

A total of consecutive 1016 intracranial aneurysm operations performed by senior neurosurgeons (HGI-YY) in the Department of Neurosurgery, University Hospital Zurich, from 1993 to 2007 were reviewed. The study was focused only on completely clipped aneurysms with no identified remnant. Nine recurrent aneurysms were encountered during this period. Six had been completely clipped at inspection according to surgical records by Prof. Yasargil until the end of 1992 but had not been confirmed by postoperative angiography. Three recurrent aneurysms were encountered and treated during the above mentioned period in which the postoperative angiography was performed routinely and complete neck clipping at the primary surgery was confirmed. The angiographies were performed and evaluated by experienced neuroradiologists of the Institute of Neuroradiology, University Hospital Zurich. In patients identified to be surgically treated for recurrence of their previously completely clipped aneurysms, surgical notes, intra-operative video recordings and angiograms were reviewed in detail. The severity of clinical presentation was assessed by the Hunt and Hess H&H grading [6] and the clinical outcome after 3 month, assessed by a neurologist in the outpatient clinic, by the Glasgow outcome scale GOS [7].

Endovascular coil embolisation was basically considered in all recurrent aneurysms as an alternative treatment method. But only one underwent the procedure and the others seven surgically treated were finally concluded not to be suitable after discussion with our neuroradiologist because of the overall complex aneurysm-architecture (wide neck, large size and/or incorporated vessel origins).

All aneurysms surgically treated were approached through the same old craniotomy and removal of the old clip when possible and/or necessary, followed by permanent

clipping to achieve complete occlusion of the neck. The application of temporary clips (mostly less than 15 min. of duration) was almost always applied during dissection of the scar tissue around the aneurysm-old clip complex, removal of the previously placed clip and up to new clip application. Intraoperative Doppler sonography was always used to confirm the blood flow in the parent artery.

3. Results

Totally 9 patients, 3 males and 6 females, were identified to have recurrence of their previously clipped aneurysms. The patient's age at the second admission ranged from 39 to 64 years (mean 49.8 ± 7.1 years). The first clinical presentation in 8 cases was subarachnoid hemorrhage SAH, while in 1 patient the aneurysm was incidentally diagnosed. The aneurysm locations were the following: 2 are on the middle cerebral artery MCA bifurcation, 4 on the posterior communicating artery PcomA at its origin and each 1 on the posterior cerebral artery PCA bifurcation(P2-3 junction), on the anterior communicating artery AcomA and on the bifurcation of the basilar artery BA. At the time of initial discharge all the 9 patients returned to normal life without any neurological disability (GOS 5). Two patients (Nos. 3 and 9) presented with recurrence of SAH while in the remaining 7 patients, the recurrent aneurysm did not rupture, i.e. was found incidentally or at the time of regular check-up: 6 patients had headache of different types (patients Nos. 1,2,5,6,7 and 8) and another patient had unspecific visual disturbance (patient No. 4). The mean elapsed time between the first treatment and the diagnosis of the recurrent aneurysm was 13.3 ± 7.8 years (ranged 1 to 25 years). Patient's characteristics are shown in Table 1.

Procedures and Technical Adjuncts: Different surgical techniques were required for each case depending on the interpretation of the preoperative angiographical findings and on the intraoperative situation encountered, especially the relationship of the old clip to the newly formed aneurysm neck. Microsurgical clipping could be performed in 6 patients. In 5 aneurysms the old clips were removed after being released from surrounding adhesions followed by reclipping of the new neck (Table 1) (Fig. 1 and 2). In two out of these 5 aneurysms (patient Nos. 6 and 7), owing to the fusiform shape of the aneurysm, fenestrated clips were used for reconstruction around the neck without sacrificing the flow in the parent artery as assessed by intraoperative Doppler sonography (Fig. 3). In another case, new clipping could be performed without removal of the old clip and without compromising the blood flow in the parent artery (patient No. 1). One MCA aneurysm (patient No. 5) was treated by coating and extracranial-intracranial EC-IC bypass between the STA and peripheral MCA branch. In this case it was impossible to remove the old clip and to reclip the aneurysm completely due to the size of aneurysm (2.5 cm) and due to extreme scar formation.

In the patient of P2-P3 junction recurrent aneurysm, endovascular occlusion of the parent artery P2 was successfully performed after a tolerable balloon occlusion test of the P2.

Outcome: There were no deaths in any of patients treated surgically and endovascularly. All 6 patients but one who were treated by reclipping of their recurrent aneurysms had a good outcome with GOS 4-5 (patients Nos. 1-4,6,7). Patient No. 5, who was treated by EC-IC bypass and coating of the aneurysm, had a poor recovery due to a postoperative intraSylvian hematoma although submitted to immediate removal on the same night. The patient (No. 8) with endovascular parent artery occlusion had a

good outcome. All the patient's outcome is shown in Table 1. One patient (No.9) died of SAH without any intervention.

Classification of recurrent aneurysms: In reviewing the surgical notes, videos and angiograms performed for each of the reoperated cases, recurrence could be classified into 3 types, depending on the relation of the aneurysm to the previously situated clip. However it was sometimes difficult to make differentiation between these 3 groups only from preoperative angiographical findings. Type A recurrence included saccular aneurysms in which the new aneurysm neck was situated proximal or distal to the clip, which was always found to be closing by the distal part of its blades on the dilated neck line and accompanying scar tissue making it almost always mandatory to remove the clip in order to gain its adequate exposure and completely secure the aneurysm. A total of 6 aneurysms were classified as type A recurrence (Patient No. 2,4,5,7,8 and 9) (Table 1, Fig. 4A). Type B recurrence (No.3) included saccular aneurysms in which the clip was partially attached to the aneurysm sack or fundus distant from the neck (Table 1). Type C (Patient Nos. 1 and 6) recurrence represented cases where the recurrent aneurysm grew in a quite separate direction independently from the old clip as was in the case of McKissok (1)(Fig.5).

4. Discussion

Few data exist on the long-term (>2 years) angiographic follow up review of surgically treated aneurysms. Necessity of late follow-up angiography for incompletely obliterated aneurysms had been pointed out repeatedly by Drake et al because of their regrowth [8,9]. In the study of a mean follow-up of 4.4 years, David et al. reported a 0.52% annual

regrowth rate for completely clipped aneurysms in a relatively large series (2 out of 135 clipped aneurysms with follow-up review of 4.4 years), by which they stated that late angiographic follow up review would not be required for completely clipped aneurysms, might be due to the negligible % in view of invasiveness of angiography [2]. On the other hand, Tsutsumi et al. reported the annual incidence of 0.26% on a series of 125 patients with a follow-up period twice long as that of David et al. stating that the cumulative risk of aneurysm recurrence reached almost 10% at 9 years including de novo aneurysm formation (0.89%/year), what would make the follow-up angiography recommendable even for patients with completely clipped aneurysm after up to 10 years post clipping [3]. A comprehensive overview of reported cases with recurrent aneurysms is shown in Table 2. A wealth of previous observations suggests that aneurysms can recur from residual rests and even from apparently perfectly clipped aneurysms [10,11,12,13,15,16,18]. The rationale for obtaining routine postoperative angiogram to detect incompletely obliterated aneurysms has been emphasized by Drake and Allcock [9]. Even though postoperative angiograms confirm aneurysm obliteration, clips can slip or break and aneurysms can regrow and hemorrhage might recur several months to years after the foregoing treatment [11,15].

In this study we focus on recurrent aneurysms, which turned out to have less incidence and to have longer elapsed period from the first surgery (13.3 ± 7.8 years on the average) as compared with other studies mentioned above (Table 2). We were able to define 3 types of recurrence which might help in the management of newly formed aneurysm; necessity of removal of old clips before new clip application, use of multiple or various clips and/or application of some other methods than clipping, combination of

bypass procedure etc. In the type A, where a part of the old clip occupy the newly formed aneurysm neck interfere together with dense scar tissue an optimal reclipping so that the old clip have to be principally removed. There is however some exception as Fig.1 B1,2 shows, in which reclipping can be performed without removal of the old clip. This type A is the most frequent one of three types. In Type B the location of the old clip is far from the aneurysm neck does not prevent new clipping so that its removal is not always necessary. In Type C, the location of the old clip is independent from the recurrent aneurysm neck, so that the old clip does not prevent new clipping. However, It should be emphasized, removal of the old clip(s) for new neck clipping is almost always recommendable, for application of temporary clip(s) or application of optimal permanent clip including multiple permanent clips after precise confirmation of anatomical situations. Use of appropriate temporary clipping technique would minimize the danger of intraoperative rupture (took place in 3 cases of our series) and resulting sequellae during the procedure

Several possibilities have been proposed as mechanism of regrowth after a perfectly clipping. Kossowsky et al. reported on an acute subarachnoid hemorrhage with intracerebral hematoma following fracture of a blade of a Heifetz aneurysm clip. The fracture mechanism was reported to be stress corrosion [20]. Ebina et al. presumed that fragility of the vascular wall (the muscular layer and the internal elastic lamina) at the clip edge subjected to the hemodynamic stress is responsible for the recurrent growth of aneurysm. They also emphasized the role of silver aneurysm clip used in their cases is known to corrode and induce a granulomatous tissue reaction, which could have increased the incidence of recurrence[11]. These factors, however, are now unlikely to be involved because contemporary aneurysm clips are made of inert materials having

high closing pressures, although some slippage mechanism at the time of titanium clip application has been pointed out [19]. In principle, MRI examination on a patient with clipped intracranial aneurysm could cause clip movement and also hemorrhage despite of initially complete aneurysm occlusion [21]. In vitro studies revealed that the Elgiloy clips showed a deflection angle of 9° with some torque movement in a 3.0 Tesla MR system, whereas titanium clip did not show any movement [22]. In the present cases, the clips used were mostly standard Yasargil Elgiloy clips and the rest Yasargil titanium clips with a closing force ranging between 102 g and 199 g and without possibility of magnetic displacement under 1.5 Tesla MRI according to the manufacturers statement. The most possible causes which could be attributed to the recurrence of aneurysms in the present series would be either a new aneurysmal dilatation over time due to continuous subjection to hemodynamic stresses at the arterial wall adjacent to the clip edge or the mechanical failure of aneurysmal clip or the presence of an unidentified microscopic rest after the first operation followed by its enlargement, that resulted in "slipped out" of the primarily applied clip. As Feuerberg et al. noted, angiographic identification of aneurysm rests can be difficult, even if postoperative angiography revealed no residual aneurysm and perfect clipping, a small aneurysm rest cannot be ruled out completely [23]. Anyway, it is difficult to ensure which mechanism was responsible for the recurrence in each of our identified groups. We cannot state from our recurrent cases whether there is a preferential site for recurrence.

Nine recurrent aneurysms patients in this study represent a very small percentage (0.9%) of the 1016 total patients treated during the study period of 15 years. Furthermore, in 6 of these 9 patients recurred aneurysms had initial surgery more than 15 years before and had no follow-up angiography. The Interval to disclosure of

recurrent aneurysms followed by their treatment amounted to as long as 13.3 years on the average. The aneurysm recurrence was around 0.01 %/year over all during the period 1976-2007 (although incomplete data before 1992) and during this study period 1993-2007 in which postoperative angiography was routinely performed indicates 0.02%/year incidence. These small percentages of aneurysm recurrence after a complete neck clipping as compared with other reports might be attributed to several factors above all: uniform microsurgical techniques including routine use of temporary clip(s) by three neurosurgeons on more than 2000 aneurysm cases, no use of clips of corrosive metals or silver, exclusive use of Yasargil clip mostly Elgiloy and less use of titanium clips. The number of recurrence after clipping procedure has been reported to be far less (less than 1/2) as compared with that after endovascular complete coiling(14,15), which could be confirmed also with this study.

By the way, it would not be always possible to obtain a follow up angiography for all treated patients especially for such a long time (up to 13 years) owing to the patient reluctance who were doing well and feel cured to submit to a stressful and uncomfortable examination associated with a small but significant risk. This problem might be mostly solved in the near future by computer tomography angiography CTA, since there are already reports suggesting 16-slice CTA might replace digital subtraction angiography for routine postoperative control of clipped aneurysms [24, 25].

Appropriateness of our classification into three types of recurrent aneurysms after a complete neck clipping confirmed by postoperative angiography need, of course, to be evaluated by further studying on a larger number group. The group should be differentiated from recurrent aneurysm group due to identified aneurysm remnant.

5. Conclusions

During the period of 1993 through 2007 on 1016 patients with cerebral aneurysms surgically treated, we have experienced 9 recurrent aneurysms; Six after completely clipped aneurysms confirmed at the time of surgery but without follow-up angiography (before 1992) and three confirmed also by postoperative angiography (since 1993). These recurrences were found even after 13 years on average after the initial surgery. Follow-up angiography might be substituted by CTA and the latter should be applied at the time of regular following up with special attention concerning this even after a long time as long as 13 years. Recurrent aneurysms could be classified into 3 types, what might help in the planning of their microsurgical treatment; new clip application with or without removal of the old clip, or other procedures irrespective of these.

Acknowledgement

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6. References

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Figure legends

Fig. 1. Case no. 7. Postoperative follow up angiography performed 1 week (A) and 10 years (B) after the initial clipping of ICA-PcomA aneurysm (arrow) showed completely clipped aneurysm. Angiography performed 10 years after the initial clipping showed an aneurysm recurrence-type A (arrow) (C).

Fig. 2. Surgeon's drawing of the intraoperative situation encountered in case no. 1. The neck of the recurrent saccular AcomA aneurysm was situated quite different place from the old clip (type C) (A). The old clip had to be removed, however, for the management of intraoperative rupture at the time of dissection of the aneurysm sac from the left A2 and to secure enough operating space for the new clipping by the temporary clipping technique (B).

Fig. 3. Artist drawing of the intraoperative situation encountered in case no. 6. The fusiform aneurysm of the right PcomA displaced the old clip to the periphery of the aneurysm fundus (A). The old clip had to be removed to gain adequate exposure and to perform a clip-reconstruction without sacrificing the PcomA (B).

Fig. 4. A: Schematic drawing of a type A recurrence. The new aneurysm neck was situated proximal to the clip. The old clip was released from surrounding adhesions (A1). The old clip had to be removed to gain adequate exposure (A2) and to completely secure the recurrent aneurysm by a new clip (A3). B: Schematic drawing of type B recurrence. The new aneurysm neck was situated distal to the clip (B1). Complete

securing of the aneurysm neck by additional clip without the need for removal of the old was possible (B2).

Table 1

Patient characteristics

Pat.no.	Age (yrs.)	Sex	Aneurysm	Side	Size (mm)	Initial H&H GOS	Second H&H GOS	Latency (yrs.)	Treatment modality of recurrent aneurysm	Group	Multiple
1.CB	39	M	AcomA	L	14	1	5	12	Clipping	C	
2.PA	64	M	MCA	L	8	2	5	17	Clipping	A	
3.SP	50	F	IC-	R	10	3	5	19	Clipping	B	O
4.OE	55	F	PcomA	R	20	2	5	20	Clipping	A	O
5.EM	51	M	MCA	L	25	0	5	25	EC-IC Bypass and coating	A	
6.WU	52	F	IC-	R	12	?	5	15	Clipping	C	
7.MB	48	F	PcomA	R	8	4	5	10	Clipping	A	
8.PL	40	F	PcomA	R	4	3	5	1	Endovascular proximal occlusion	A	
9.KE	49	F	BA-bifur		6	1	5	1	x	A	

Pat.no.: patient number, yrs: years, M: male, F: female, L: left, R: right, Initial: severity grade and outcome at first admission, Second: severity grade and outcome after second admission, Latency: latency to diagnosis of the recurrent aneurysm

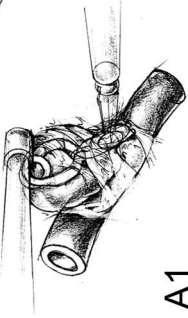
Table 2

Clinical data of similar cases reported in the literature

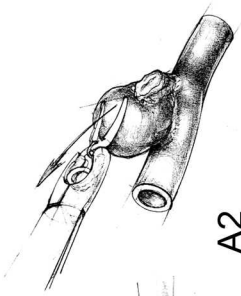
First Author	Year	Aneurysm	Presentation	Latency	Possible mechanism	Treatment modality	GOS
Kossowski [18]	1982	PcomA	ICH	22 month	Clip fracture	None	1
Drake [8]	1984	PcomA	?	5 months	Slipped clip	Reclipping	?
		BT	?	7 years	Slipped clip	Vessel occlusion	1
Klucznik [19]	1993	MCA	ICH	14 years	Magnetic field	None	1
Amagasaki [16]	2002	AcomA	SAH	8 years	n.a.	Reclipping	?
		BT	SAH	15 years	n.a.	Reclipping	?
		MCA	SAH	12 years	n.a.	Coiling	?
		PcomA	SAH	14 years	n.a.	Reclipping	?
Asgari [15]	2003	MCA	ICH	25 days	Slipped clip	Reclipping	3
		AcomA	ICH	1 month	Slipped clip	Reclipping	2
		MCA	ICH	48 month	n.a.	None	1
Kashimura [17]	2007	AcomA	SAH	11 years	n.a.	Reclipping	4
		AcomA	SAH	15 years	n.a.	Reclipping	5
		AcomA	incidental	19 years	n.a.	Reclipping	5
		MCA	SAH	12 years	n.a.	Reclipping	5

Presentation: clinical presentation of the recurrent aneurysm, Latency: latency to diagnosis of the recurrent aneurysm, ICH: intracerebral hemorrhage, SAH: subarachnoid hemorrhage, n.a.: information not available

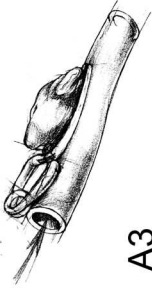




A1



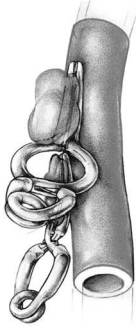
A2



A3



B1



B2

